REMOTE SENSING AND PREDICTION OF THE COASTAL MARINE BOUNDARY LAYER

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LONG TERM GOALS

The long term goal is to improve numerical (computer -aided) weather prediction in coastal regions, especially of weather events that impact naval operations.

OBJECTIVES

The objectives are two. First, we aim to develop more accurate and efficient ways to represent atmospheric physical processes in numerical weather prediction (NWP) models. Second, we aim to improve the real-time processing of atmospheric observations, especially from radars and satellites, for NWP model initialization.

APPROACH

The physical processes we are studying for the purpose of better representing them in NWP models (the "parameterization" process) mostly involve low, boundary layer clouds (fog, stratus). Our research program has a tool known as a large eddy simulation (LES) model, with fairly detailed, accurate representations of physical process that occur in the atmospheric boundary layer (the lower ~1 km of atmosphere that is constantly exchanging heat, moisture and momentum with the surface of the Earth). The model has been verified against data from several field programs. The LES model is then used to find relationships between physical processes and states (such as drizzle production, aerosol cleansing, visibility, cloud cover, optical properties) and physical variables that are (or can be) forecasted in NWP models (humidity, aerosol concentration, etc.).

The LES model is also used as a guide to construct NWP parameterizations that will allow for stratocumulus clouds to break up naturally into honey-comb cloud patterns known as mesoscale cellular convection, or MCC. (The individual cells of MCC are typically 30 km across). The LES model output is treated as data. In constructing an NWP model as a subset of the LES model, inessential processes are thrown out or simplified if the ability to simulate meoscale cloud structures is retained.

A third project to improve the computer representation of the atmosphere is to design and implement an algorithm that continually moves gridpoints around in the vertical direction, into layers where they are immediately needed. ("Gridpoints" are the locations where values of atmospheric variables are stored - in almost all NWP models the locations do not change with time.) These layers where more gridpoints are needed are cloud layers and/or layers of strong vertical gradients.

Our approach to better initialize atmospheric models involves using radar and satellite data to retrieve atmospheric quantities, and using the retrievals in constructing a physically consistent state of the current atmosphere. Specifically, we emphasize retrieving quantities that define structures with scales in the range of 1 to 100 km. These could be convergence lines, three-dimensional cloud positions, water vapor distribution, boundary layer height, squall lines, seabreeze convergence clouds, fog or low-clouds. Single-Doppler retrieval has a long history of development at the University of Oklahoma, a tradition we continue. The single-Doppler "problem" is to retrieve as much information about the wind vector and thermodynamic state as is possible from a time-series of radar measurements that at any instant in time is measuring only the component of wind aligned with the radar beam. Our precise approach to satellite data is unknown at this time; we intend to emphasize mesoscale and boundary layer structures of the atmosphere, sea-surface and land-surface temperatures, and precipitable water vapor.

WORK COMPLETED

Five post- "docs" and a technician have been hired. The post-docs are Dr. Fanyou Kong, Dr. Zonghui Huo, Dr. Qingfu Liu, Dr. Pengfei Zhang, and Dr. Chinnaswamy Arulmani. An extensive array of networked workstations has been installed, with access to shared DEC Alpha workstations and the University of Oklahoma's (OU) CrayJ90.

Much of the testing of our new ideas involves the use of existing NWP models: OU's Advanced Regional Prediction System (ARPS) model and the Navy's COAMPS model. An important first step completed this year is that the newly hired scientists learned how to use and improve these models. They have developed important interfaces that allow the models to share information with each other.

The COAMPS model was originally designed to be initialized using the same data as the NAVY's global model NOGAPS. The COAMPS forecast gives benefit over that of NOGAPS mainly in that COAMPS better resolves topography, coastlines and atmospheric events like thunderstorms, than does NOGAPS. There has been no extensive effort to incorporate extra retrieval schemes or assimilation schemes specifically for COAMPS.

On the other hand, there has been extensive development at OU to assimilate high space and time-resolution observations from both radar and surface networks into the initialization of ARPS, so as to better predict future thunderstorms and other mesoscale phenomena. The COAMPS and ARPS models are sufficiently similar that the COAMPS initialization can be successfully run through the ARPS Data Assimilation System (ADAS) with a simple software interface produced by our colleagues, Dr. Qin Xu and Dr. Wei Gu. Their recent work has shown that, with ADAS, COAMPS successfully predicts an Oklahoma squall line, without it, COAMPS does not.

ARPS has existing interfaces that allow it to nest in the NCEP forecast models: ETA and RUC. CMRP has built the software interface that allows ARPS to nest in NOGAPS using the COAMPS initialization. Dr. Zonghui Huo used both ARPS and COAMPS to successfully model the 23 April 1997 squall line over Florida, both models having been nested in NOGAPS.

The original proposal emphasized that CMRP would modify ARPS (ultimately into a model called Coastal ARPS, or CARPS) which, in comparison with COAMPS, could be used to demonstrate the value of new algorithms developed by CMRP. CARPS now has a moving-grid capability. We have successfully applied this capability to idealized boundary layer waves, where it is fairly obvious how to specify a redistribution of the gridpoints. The moving grid adds only a 4% increase to the CPU time, per time-step. CARPS also has a drizzle parameterization based on the work of Dr. Yefim Kogan and implemented by Qingfu Liu. Dr. Fanyou Kong has enhanced the numerical integrity of the microphysics schemes and implemented an efficient positive-definite, conservative advection scheme, thus removing the use of an artificial source to "fill in" the negative values. Dr. Wong has implemented an efficient cloud-radiation interaction into the CARPS. Dr. Kong has begun simulations of low cloud on the California coast with the ARPS/CARPS.

The drizzle parameterization consists of 6 prognostic variables: cloud water content, cloud drop concentration, total mean radius, drizzle water content, drizzle concentration and
cloud condensation nuclei. The mesoscale version of this drizzle parameterization is similar to that which was developed by Dr. Kogan for LES models, except the mesoscale version does not use or predict supersaturation. Instead, an empirical formula is used for activation of cloud condensation nuclei.

Dr. Alan Shapiro has developed a new 4DVAR single-Doppler retrieval technique. The retrieval is Lagrangian in nature and uses Newton's second law as a strong constraint. The scheme was successfully verified against a dual-Doppler data set for a squall line in central Oklahoma on 7 May 1995. Dr. Wurman deployed OU's mobile radars in South Florida from 16-23 August 1997. Dual Doppler data sets were collected that can by used by Dr. Shapiro to verify his single-Doppler retrieval schemes. Some of the data sets collected have scanning rates as high as 1.5 minutes/volume, and are appropriate for establishing the sensitivity of the retrievals to data of progressively degraded (thinned) temporal resolution.

Dr. Brian Fiedler has run the ARPS model as a high resolution (125 meters) *dry* LES in a 32 km square domain with periodic boundary conditions. Large-scale convection cells emerged over the course of two days until a single-cell dominated the domain. The LES simulations were then compared with the ARPS run as a mesoscale model with 1 km resolution, where most of the cumulus-scale transport was sub-grid. Various sub-grid mixing-length parameterizations were tested, with the intent of finding the best match with the LES. The mesoscale modeling of MCC is now proceeding with detailed physical schemes, some of which were produced by Dr. Kogan or Dr. Wong. We will soon apply the moving grid and the latest developments in Dr. Kogan's mesoscale microphysics schemes, as they become available.

RESULTS

The CMRP is well on the way to becoming the competent user of COAMPS and developer of CARPS, as was promised in our proposal. We are poised to exploit this knowledge in a study of how satellite and radar products can reduce the spin-up and lag of the squall line forecast and how satellite products can improve a California stratus forecast. We also note here, with our knowledge of how COAMPS is constructed, we have found that it would be surprisingly easy to transplant code from ARPS into COAMPS.

Dr. Kogan's has moved his aerosol and drizzle parameterization projects forward on the LES front, and has established a beachhead for his algorithms in a mesoscale model. Dr. Fiedler has completed a theoretical study of MCC that allows for intelligent construction and troubleshooting of mesoscale NWP modeling of MCC.

Dr. Shapiro's new 4DVAR single-Doppler scheme is complete and ready to be tested by Dr. Wurman's Florida dual-Doppler sets and model generated "perfect" data.

IMPACT

Our results are not yet known in the meteorology community or Navy.

TRANSITIONS

The COAMPS development team at NRL is aware of our developments and has been offered some of our software products for immediate use.

RELATED PROJECTS

We work closely with the personnel of OU's Center for Analysis and Prediction of Storms.

REFERENCE

CMRP presented 3 conference papers this past summer and will present 5 in January at the Annual Meeting of the American Meteorological Society .